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THE NATURAL IMPROVEMENT OF SOILS.

BY

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PREFACE.

Harrisburg, Pa., September 1, 1902.

The following Bulletin No. 102, by Edward B. Voorhees, M. A., Director of the New Jersey Agricultural Experiment Station, upon "The Natural Improvement of Soils," discusses this important subject from the standpoint of a scientific investigator, in language familiar to the practical farmer.

Director Voorhees explains the character of the physical differences of soils, the effects of living organisms in the soil upon soil improvement, the conservation of moisture by tillage, the use of lime and the various forage plants in their regeneration.

Soil improvement by cheap and easily available means, is the great problem in modern agriculture. When soils were new and consequently fertile, the securing of sufficient fertility for an abundant crop required almost no expenditure of money, and very little thought, but now when soils in the east are becoming unproductive the question is most important, and farmers are anxiously looking for information which shall help them in restoring their farms to their old state of fertility at minimum cost.

This bulletin will greatly assist those who study it in securing this result, and it is, therefore, commended to all who are interested in the subject of soil improvement for agricultural use.

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JOHN HAMILTON,
Secretary of Agriculture.

LETTER OF TRANSMITTAL.

New Jersey Agricultural Experiment Stations,
New Brunswick, N. J., August 20, 1902.

Prof. John Hamilton, *Secretary of Agriculture, Harrisburg, Pa.:*

My Dear Sir: I hand you herewith a bulletin on "The Improvement of Soils," prepared at your request. In this bulletin I have taken great pains to collect accurate data, and have attempted to present the matter in such a way as to appeal to the practical farmer.

Very truly yours,

E. B. VOORHEES,
Director.

THE NATURAL IMPROVEMENT OF SOILS.

By Edward B. Voorhees, M. A., *Director of the New Jersey Agricultural Experiment Stations.*

The farmer's primary source of income is the soil, the success of his operations, therefore, depends upon its original composition and character, its management and the handling of the products raised. The management of a soil, however, is quite as important a factor as the character of the soil itself, for it may be directed in such a way as to result either in rapid impoverishment, or in great improvement in productivity. In other words, the man is the most important factor in farming, as in other lines of business.

How Soils Differ.

In studying the nature of soils, we find that they possess two distinct characteristics, which have a direct bearing upon their fertility, or crop-producing power; one of these characteristics is the chemical, or the power which soils possess of furnishing those constituents that are necessary in the growth of plants, though it is not necessary that soils, perfect from the chemical standpoint, that is, that can furnish an abundance of the essential plant-food constituents for all kinds of plants, shall contain the constituents in the same proportion as they are found in plants. In fact, because of the origin and nature of soils, those constituents which are contained in them in maximum amounts are found in plants in minimum amounts, while on the other hand, those constituents which are contained in plants in maximum amounts are found in minimum amounts in soils, thus making the value of a soil from the chemical standpoint dependent rather upon the relative amounts of the four constituents, which by the continuous growth of plants are removed more rapidly from the soil than the others, viz: nitrogen, phosphoric acid, potash and lime. These are, for this reason, called essential manurial constituents, and the wide differences in soils in respect to their content of the substances which furnish them are due to the changes which were wrought in the surface of the earth during its formation, to those which have taken place since, as well as to those which are going on in a small way even at the present time.

It is believed that the original earth crust contained all the minerals now found in it, and that at the beginning they were distrib-

uted more uniformly throughout its mass than at present. In the harder rocks, the sandy particles were cemented together by materials more easily disintegrated and the separation thus made in the course of time enabled the movement of the particles so separated in a different way, the coarser materials were distributed and deposited as gravel and sand in one place, and the finer carried and deposited in another, making the clay; the lime entered partly in solution, and was distributed and finally deposited in another place, thus giving us sandy, clayey and limy soils, all differing from each other in their amount and proportion of both the purely mechanical substances, which serve no other purpose in soils than the support of the plants and in contributing to physical character, and of the chemical substances which contain the essential fertilizing constituents, and which in their decay provide the food in an available form.

In addition to these kinds of soils, there are others of more recent origin, made up largely of vegetable matter, due to its accumulation in a partially decayed state; these are frequently rich in nitrogen and poor in all of the essential mineral constituents. These considerations as to the origin of soils are valuable in indicating their chemical composition and possible potential value.

Chemical Differences in Soils.

In the next place, fertility depends not altogether on the amount and proportion of the essential constituents contained in soils, but also upon the character of the mineral substances which contain them, that is, whether they are of such a character as to be readily disintegrated or broken down, or whether they are hard and dense, and thus resist those agencies which are active in causing such disintegration. It is quite possible for a soil to be rich in all of these constituents, and still be infertile, because the character of the substances making the soil are such as to prevent their ready attack by those agencies which cause the constituents to become active.

Physical Differences in Soils.

The second valuable characteristic of soils is their physical character. This characteristic is not altogether separate and distinct from the chemical, nevertheless it has to do more particularly with the purely mechanical substances contained in soils and their fineness of division, and has an important bearing upon the actual fertility. In order that we may understand this matter more clearly, it is well perhaps to point out that the substances which constitute the bulk of soils are in an insoluble condition, while the plants

take up their food in a soluble condition, hence changes must take place in these substances before they can serve as plant food. The plant roots themselves assist to some extent in causing this change, thus rendering the constituents soluble, still, the great factor in this change is the action of those natural forces, water, sun and air. Water has a solvent effect upon the constituents of soils, and unless it can freely penetrate and reach every portion of the soil its power is very much reduced. That is, if the soils are so compact and dense as to prevent the free penetration and movement of water in the soil, the plants are not able to readily obtain their food, and thus make maximum growth and development, because enough is not distributed throughout those soil layers to which the plant roots are limited. On the other hand, soils that are too open and porous, that are made up of rather coarse particles of mineral substances, as, for example, sandy soils, made up chiefly of quartz, the water penetrates and moves too freely, and the dissolved constituents that are present are too readily carried away from those parts of the soil in which the plants obtain their food, thus again not providing the best condition for its appropriation.

Furthermore, the reservoirs of water under these soils, or in the subsoils, and which are also extremely essential, are rapidly depleted, as the water escapes very freely from the soil in the form of vapor, and this prevents the plants from obtaining so large a proportion of the water that is stored in the earth, as if the conditions of soils were such as to prevent the free escape from the surface. Between these two extremes of soils, first, those with very finely divided particles, making the soil too compact and thus impervious to water; and second, those that are made up of coarse particles, we may have a mixture of the two, which is probably well represented by what is understood as a loam, which possesses in part the properties of each in such a degree as to make the movement of the water more nearly perfect in respect to its supply to plants. That is, we obtain the solvent effect of the water, as well as the free movement of it, which contributes both to the solution of constituents and their movement throughout the soil where needed. It, therefore, frequently happens that from soils reasonably rich or even very rich in chemical constituents, results are obtained that are far below what might be expected from the composition of the soil, because their physical character is such as to prevent the movement of water, and consequently the necessary changes which make it possible for the plant to obtain its food. These considerations are also true in a degree in reference to the action of the other natural agencies, air and warmth. Only in the case of those soils which possess good proportions of the various substances making up soils, do we receive the full benefit of Nature's aids.

The Biological Character of Soils.

The physical character of soils, also, has an important bearing upon the question of the living organisms in the soil, whose activity in improving soils is very important, though not appreciated until recent years, and not yet fully understood. Soils are not, as has been believed to some extent in the past, dead things, serving only as banks from which we may draw out deposits of materials, already in a state capable of serving as food, but are rather laboratories, in which the natural agencies, already described, are actively engaged in working over the raw materials, converting them into forms available for use. They contain millions of living creatures, small to be sure, which depend for their life upon air, moisture and the insoluble matter in the soil, the latter of which in the transformation which takes place in the growth of organisms, is changed into forms which the plant can absorb.

It must not be forgotten that these lower orders of life depend for their best growth and development upon the conditions that are favorable for the life and growth of the higher orders of life, namely, food, moisture and warmth, and as the farmer by his practice makes the conditions favorable for their life and thus encourages their growth, he provides for a more rapid change of soil substances, while on the other hand, if he by his practice prevents or in any way reduces the opportunities for the life and growth of these agencies, he reduces in just that degree the possible usefulness of the potential fertility of such soil. For example, the farmer who allows his soil by improper treatment to become compact and hard, thus not permitting the free movement of air and water, is making the conditions unfavorable for the living organisms in the soil, and is preventing in part the change of insoluble into soluble substances, the result of which is food for the plant; while, on the other hand, the farmer who by his practice makes the conditions for life in the soil favorable by controlling the movements of water , warmth and air, obtains from his soil a larger crop, because he has directed in an intelligent way the agencies which assist in the change of soil substance, and which is necessary in order to insure an abundance of available food, which assists in the natural improvement of soils. Improvement of soils may, therefore, be brought about, and without expense, by assisting Nature, in changing for the better both the chemical and physical character of soils, and by controlling the movements of the soil solutions. Efforts in this direction may be called "natural methods of improvement," because the aim is to assist Nature in her work which results in changing potential or possible into active, or actual fertility, rather than to add to the soil substances which contribute directly to the store of active constituents.

The Conservation of Moisture.

While the chemical and physical character of soils are of primary importance, and do in a large degree determine the possible productive power of soils, still the handling of the soil possessing these characteristics even in a high degree is of equal importance. That is, a soil however perfect as a place for the growth of plants, or however rich in the plant-food elements, cannot be productive without water, and the amount of water that plants may have at their disposal during periods of limited rainfall is measured in large degree by the methods of practice used. This point is of so much importance and has so intimate a bearing on soil improvement that it warrants a rather detailed discussion of the question of the conservation of soil moisture.

Water is one of the most important constituents of plants. If perfect growth and development are to be attained, it is necessary that the plant shall be able to obtain a full supply during its entire period of growth. It is not simply a question of water, however, for the water that plants use must exist in a special form in the soil, and it must exist there in proper amounts. Soils may contain too much or be too wet for the proper growth of the most useful plants, if the water is not located in the right place. Water exists in soils in three forms; first, free, or running water, or bottom water, or that which fills the soil, and rises and falls as it is increased or decreased by more or less percolating into it from the rains—the point to which it rises is called the water level; second, capillary water, or that held by the adhesion to the soil particles, and which fills the openings between the particles; and third, hygroscopic water, or that held firmly by the particles of soil. Land is too wet for growing plants if there is too much free or running water, or if the water level is near the surface, as it prevents the circulation of the air and the penetration of the roots to sufficient depths.

Plants do not, as a rule, use the running water; they are able to obtain all they need when land is moist rather than wet. For this reason the water in soils useful for plants is usually referred to as the moisture rather than the water of the soil. This moisture of the soil is really, therefore, the capillary water, or that held by adhesion to the soil particles, and while there may be too much capillary water in soils for the best development of plants, because certain kinds of soils may absorb too much, it is not usually a serious matter, because the difficulty can be readily remedied, as will be pointed out later.

The hygroscopic water is that which is very slow to escape, in fact, it must be driven out of the soil. That is, soil which appears to be absolutely dry may still contain this hygroscopic water, and

in order that it may be perfectly dry, it must be driven out by heating the soil up to the temperature of boiling water for a considerable period of time—at this temperature (212 degrees Fahr.) the water vaporizes and escapes into the air. Naturally, this form of water in the soil is not a useful one for plants, as it exists in soils after plants have perished for lack of moisture.

Rainfall the Source of Soil Water.

The water in soils is due to the rainfall; the water-level in the earth rising in seasons of greatest rainfall, or wet periods, and falling in dry periods, hence, while the water that plants obtain is due to rainfall, it does not follow that it shall occur immediately preceding or during the season of the plant's growth. For example, there are places where the rainfall in the course of a year is so great as to provide such a total excess of water as to cause the soil to be thoroughly saturated, or to keep the level so near the surface as to prevent the growth of plants, yet luxuriant crops are grown in these places. This is explained on the ground, first, that while the average rainfall is so great as to cause the soil to be thoroughly saturated, the time of the rainfall is such that during the crop-making season a sufficient amount only is provided for the plants; that is, that which falls during the season that crops are not growing partly sinks into the soil and partly runs off, and by the time the crop-season is ready, the water level is lowered sufficiently to enable the plants to throw their roots deeply, and they are fed with the capillary water drawn from the reservoirs below, which were filled by the preceding rains; and second, though the rainfall may be, on the average, too great, the soil is of such a character, open and porous, as to enable the rapid percolation of it to lower levels, and the climate such as to cause a rapid evaporation of it into the atmosphere. The moisture that may be obtained from rainfall is, therefore, influenced by two conditions, the time of its precipitation and the character of the soil upon which it falls.

An Even Distribution of Rainfall Desirable.

The water from the immediate rainfall to be most useful to plants should be distributed evenly throughout the growing season; in such cases, a minimum precipitation would provide for a maximum production, if the soil is of such a character as to retain and hold that which falls upon it for the use of the plants. Therefore, while rain is the primary source of water to plants, needed amounts may be obtained from underground supplies. That is, the season of rainfall may occur during the time when plants are not usually growing, but the water sinks into the soil which holds it as in a reservoir,

and as the plants grow the moisture is gradually drawn to the surface by the influence of capillarity, and the amount necessary for full production is obtained, and while its original source is the rainfall, the immediate supply to the plant is derived from that which has fallen a considerable time previous to the period of growth of the plant.

Wet and Dry Seasons.

In countries and States where the year is divided in respect to rainfall into a rainy season and a dry season, the above considerations are well understood, and methods of practice which shall result in the conservation of moisture are of the greatest importance. In what are called the humid regions of the country, the crop does depend in many cases more largely upon the immediate rainfall than upon that which has fallen previously, and in these regions there are seasons when periods of drouth intervene, which make it necessary that a study should be made of the causes which contribute to the rapid escape of water from the soil, and thus make the supplies insufficient to furnish plants with what they need during the growing season.

The Loss of Water From Soils.

Water escapes from the soil by rising to the surface, where it is vaporized, absorbed by the atmosphere and carried away by the wind. The escape of water is, therefore, principally due to capillarity, for as the dry air passes over the surface of the earth, as well as circulating through the surface area, it absorbs all the moisture it comes in contact with; more moisture then rises from below to take its place, and so on until only the hygroscopic water is left in the surface, or within the reach of the roots.

It has been observed that all soils in the same climate do not become dry at the same rate. That is, one soil will remain wet, another reasonably moist, and another absolutely dry, as far as plant growth is concerned, and these in many cases may all be located on the same farm. These differences are due to the character of the soil, or the particles that constitute it, which have a greater or less power of retaining or holding fast to the moisture contained in it. Or, in other words, the character and texture of the soil influences the rate at which the water will escape. By character of the soil is meant its composition, both in reference to the minerals that are contained in it, as well as the size of the particles of which it is composed, or its texture.

A clay soil will hold water more tenaciously than a sandy soil. The clay soil is composed largely of a mineral known as silicate of

alumina, capable of very fine division and close compaction; the sandy soil, on the other hand, is usually made up largely of quartz, a substance hard and stony, and not easily compacted. The clay, which is more finely divided and does not consist of stony particles, can be compacted so closely as to prevent the rapid escape of moisture, whereas the sandy cannot be readily compacted; it falls away again after pressure and the air and water circulate freely through it. As a broad, general rule, the finer the texture of a soil, the more retentive of moisture it is, and the coarser the texture the more readily will the water escape from it. In the first place, then, the greater or less retaining power of soils for water is due to their physical character, and in order to increase or decrease their retentive power their texture should be changed.

It must be remembered, however, that there is such a thing as a soil being too compact from the standpoint of moisture to plants, because this fineness and compactness prevent the ready penetration of the moisture into it; whereas, the open, porous soil permits its ready penetration, thus the one will, because of its compactness, result in the water flowing off rather than into it, and hence it will not always have as much moisture at a certain definite time after rainfall as the one which is more open and porous, and which permits a larger direct absorption and a ready percolation into the lower layers or reservoir below. Therefore, in the study of soil moisture in reference to the plant's needs, improvements of physical character are found to be of service, both in the humid and semi-humid districts, as well as in the arid or semi-arid, where irrigation is practiced; in the case of the easily compacted soil, to enable a greater absorption of that which falls and in the open, porous soil, to cause a greater retention of that which is absorbed.

The improvement of clay, or finely divided soil, should consist of such operations as will separate the particles, and make the soil more open and porous; this may be accomplished by the introduction into the soil of such substances as will coagulate, or bring together the fine particles, thus making the soil more porous. For example, liming a clay soil does improve its physical character and makes it more absorptive; it seems to have the power of collecting the very finely divided particles and partially cementing them into masses, and making the particles larger, thus making the openings between them greater, which permits a readier penetration into them of water and air. So, too, the introduction of vegetable matter, as coarse manures, influences and improves clay soils in this respect; the absorptive power of the soil is increased by the separation of the particles, not only, but because a substance has been introduced into the soil, which in itself has a greater absorbing power.

In the case of the sandy soil the same methods may be used, though the results are directly the opposite of those in the case of the clay. The addition of the lime, for example, has a tendency to cement together and to solidify the stony particles, thus closing up many of the pores and preventing the too rapid percolation of the moisture to lower levels, as well as its rapid escape, while the introduction of vegetable matter improves largely because the matter itself has a greater absorbing and retaining power than the mineral constituents of the original soil.

The aim, therefore, in both of the cases referred to is to get into and to hold in the soils of various kinds the water that falls in the rains, and conserve it for the plant during its entire period of growth. That is, all methods of improvement are based upon the principle that water that is most useful to the plant is absorbed or held by capillary attraction, and that its escape is due to the same cause or capillary attraction. Where water exists in soils in the running or free state, or in a form not useful to plants, where the water level is too near the surface, the improvement then must consist of operations which will lower its level in the soil so that an abundance of room may be provided for the distribution of the roots of the plants, and in order that the circulation of the air may not be impeded, drainage is necessary here, and will be discussed later.

Amount of Water Required by Plants.

The amount of moisture that is consumed by a growing plant is comparatively enormous, that is, the amount of water required for growing a crop is very great in proportion to the dry matter contained in it. On the average, in order to obtain one pound of dry matter in the crop, over 300 pounds of water will be required; that is, over 300 pounds of water must have been obtained by the roots and carried up through the plant and sent into the atmosphere from the leaf surface. Hence, some idea of the very great amount of water that is necessary for the growth of a large crop is gained. For example, a crop of hay from an acre of land, which contains a ton (2,000 pounds) of dry matter, would not be regarded as a large crop, yet in order to obtain it, there would be required over 300 tons (600,000 pounds) of water, and since plants vary in their needs, the maximum requirements for a pound of dry matter may be as great or greater than 600 pounds, or, in other words, large crops may draw as high as 2,000,000 pounds of water from an acre.

While the object in the conservation of soil moisture is to hold it for use of the crop, it must not be understood that all crops are equal in respect to their requirements. Crops differ widely in respect to their use of soil moisture, depending upon the kind of crop, the length of their period of growth and the object of their growth.

As a broad general rule, the broad-leaved plants and those which do not throw their roots deeply into the earth require more moisture in proportion to the dry matter contained in them than the finer-leaved plants, than those with less leaf surface and whose roots penetrate more deeply into the soil. For example, plants belonging to the grass family, as the grasses, useful for hay, and cereal grains, which do not present so large a leaf surface, and whose roots have a tendency to go deep into the earth, do not use up the moisture as rapidly as the legumes, or many of the vegetables, which have a larger leaf surface. The latter require the maximum amount of moisture in the soil, and suffer seriously immediately there is any lack.

While the total amount of water used may be the same for different plants, the time required for their growth and maturity must also be considered. A crop of wheat, for example, because it requires a longer season for full maturity may obtain its necessary moisture, though the soil contained too low a percentage to enable a potato crop, which grows and matures quickly, to obtain a full supply; a short drouth would not materially injure the wheat while it might ruin the potato crop, because of the difference in the length of the period occupied in the growth of two crops.

Where the object of the growth is succulence, and the leaf or root constitutes the crop, as in the case of many vegetables, as lettuce, beets, etc., an abundant and continuous supply of moisture is of greater relative importance than where the object is maturity, and the seed constitutes the crop, because any delay in growth in the former caused by lack of moisture is accompanied by a reduction in quality, as well as yield; whereas, in the case of wheat or other cereals the influence of delays in growth are more readily overcome, besides the yield rather than quality is affected. These considerations are useful in suggesting kinds of crops to grow under conditions of known rainfall.

A careful review of the principles here pointed out shows the importance of adopting and using methods that will aid as far as possible in retaining in the soil the moisture necessary for the growing plant; or in other words, to so direct it that it may pass through the plant into the atmosphere, rather than directly into it from the surface of the soil.

Conserving Moisture.

To do this, is called "conserving moisture," and many of the operations of the farm, which are now carelessly performed, which result in useless losses of moisture, may be changed so as to make them assist very materially in saving it for the use of the crop, and while

the location of the soil, its character, its composition, its texture and the kind and character of crops all exert an influence, and while the principles as pointed out must be understood, the judgment of the farmer must be exercised in using the various methods that may be suggested, in order that they may apply to the best advantage in his particular case.

What is Meant by Tillage.

In the first place, tillage results in conserving moisture, that is, tillage, while ordinarily performed for the sake of getting the land in condition to receive the seed, and for the sake of removing or preventing the development of foreign growths, may be carried out in such a way as to accomplish not only these objects, the primary purpose in the minds of many, but also to accomplish great things in preventing useless loss of moisture, and thus result in providing the plants with their normal requirements. Tillage consists ordinarily in plowing, cultivating, harrowing and rolling, and each of these operations may be so directed as to needlessly waste soil moisture, or to conserve it. Just how plowing has an influence in conserving soil moisture is readily understood when we remember that the moisture contained in the lower layers of the soil escapes at the surface of the soil by means of small holes or tubes formed by openings between the particles; in the process of plowing these openings or tubes are broken and the escape of the moisture from below, if not prevented altogether, is considerably retarded until sufficient time has elapsed to form the connection again with the surface. Therefore, it makes a great difference in plowing whether the furrow is thrown in a solid mass or whether when the furrow is turned the soil breaks into fine particles so that the entire surface is really a mass of separate soil particles. In the first case, the soil remaining solid the connection between the surface and the lower layers of soil is readily made, while in the second the loose mass of soil particles prevents a ready connection, considerable time must elapse before the capillary tubes join the surface with the lower layers. Naturally, the moisture contained in the soil turned by the plow will be liable to escape more rapidly than before, because the freshly turned surface is immediately presented to those natural agencies, namely, air and warmth, which are potent in drawing out and carrying it away. Nevertheless, the great reservoirs lying underneath are proof against these forces, in proportion as they are protected by the completeness or incompleteness of the soil mulch made in the process of plowing.

The Effect of Tillage.

In the next place, the moisture in the surface soil may be very largely retained if shortly after the plowing is done the cultivator and harrow are used to make still more fine the particles of earth thrown up by the plow, thus retaining in part that which would escape if the tillage were not practiced. Tillage, to conserve moisture, while confined to the cultivated crops, as corn and potatoes, does exert an influence also upon these crops, which by virtue of their character cannot be cultivated, as hay, wheat, etc., as well as upon the others, because previous tillage, viz: harrowing, plowing, etc., are operations which result in breaking up the particles of soil and thus making the surface soil itself a place where water will penetrate more readily and freely, as well as enabling the roots to ramify freely in every direction, and giving them a larger surface area from which to draw their moisture in times of drouth or in frequent rains. It is apparent, therefore, that tillage exerts an influence in conserving the moisture, not only for the immediate crop, but for future crops as well, because improving the soil in such a way as to make it more absorptive and retentive of the water which falls a considerable time previous to the planting of the crop.

The Object of Drainage.

In the next place, drainage is an important operation in improving the absorptive and retentive power of soils for water. A common idea is that drainage by lowering the water-table is only intended to remove the moisture that is present in too great amounts and that it does not exert any influence in providing moisture for crops during a period of insufficient rainfall. This idea is in part erroneous, for the very fact that the water-table is lowered enables a more rapid percolation of the water of the rains in every direction in the soil, than if the drains were not there, and as the water percolates and is absorbed more fully, the crops that follow have a larger area of moist surface to draw their water from than if the surface area of the soil through which the roots can penetrate was limited. Besides, the lowering of the water-table has a very important influence in improving the absorptive property of soils by virtue of the fact that it enables the penetration of the air to greater depths, which changes its physical and mechanical character, making heavy soils, particularly, more open and porous.

The Advantages of a Mulch.

Another method which is only practicable for small areas, is the use of a mulch, which may consist of any loose material spread over

the soil and which acts as a blanket to prevent the rapid escape of moisture into the atmosphere. The principles involved in this case are quite similar to those described in the case of tillage and plowing. The water is prevented from escaping because the mulch distributed upon the surface soil prevents the immediate contact with it of the hot, dry winds; these affect first and directly the mulch itself, which protects and cools the surface. The use of mulches for small areas is very helpful, and while not practicable on large areas it can be made of practical value in gardens and orchards and for special purposes.

Growing crops are regarded as of use, also, in conserving moisture, though in a different way, particularly in the humid climates, since a soil well covered with a crop will absorb proportionately more of the rainfall than one lying bare, largely because it prevents surface drainage. Furthermore, the rapid escape of the water in the atmosphere is prevented because, as in the case of the other forms, the winds do not come in immediate contact with the soil, thus more of the moisture passes off through the crop rather than directly into the atmosphere. In the case of crop mulches grown as a catch for the primary purpose of covering the soil between the regular crops of the rotation there is a further advantage in that the vegetable matter accumulated by them is incorporated with the soil, which is materially improved because of the introduction into it of a substance which in itself, as already pointed out, has a higher absorptive power. This vegetable matter as it decays becomes what is known as "humis," a substance which exercises a very important influence upon the productive power of the soil.

Burning Straw a Wasteful Practice.

In many sections of our country, particularly in those States which possess soils rich in fertility elements, it is the custom to burn straw and other refuse vegetable matter. This is a bad practice, for even if it is not needed for improving the productive power of the soil in respect to other elements, if it is used as a mulch and incorporated with the soil it would assist very materially in retaining moisture for crops during the period of insufficient rainfall. If the straw is not needed for bedding and other purposes it should be distributed over the land, serving first as a mulch and then incorporated with the soil, thus improving its absorptive and retentive power.

The Effect of the Rolling.

Rolling the soil is another means by which moisture may be conserved, though the results of the use of this tool should be

understood. Its best use is in the preparation of the soil for seeding by mashing lumps and clods, in solidifying it and making it fine and friable. If used after seeding, it compacts the soil and leaves the surface smooth, thus providing the very best conditions for the rapid movement of air over the surface and, therefore, causing the ready abstraction of the moisture from it. It should not be freely used on heavy clay soils that are often already sufficiently finely divided and which are liable to become too much compacted, even under natural conditions, but rather upon open soils, those that are of a loose nature, as sandy and gravelly, in order that the particles may be pressed closer together, and thus to prevent the rapid escape of the water. Nevertheless, in dry seasons the roller is useful at time of seeding, because the compacted surface and the greater evaporation therefrom cause a rapid drawing up of the water from the lower layers to the surface of the soil, enabling a quicker germination and a more rapid early growth. In other words, the rolling tends to draw the moisture from the lower layers to the surface layer, and its use can be recommended after seeding under the conditions named. The roller should be used during the preparation of the soil, and if used after seeding the surface should be again stirred by a harrow, which makes a light soil mulch, or after it has performed its function in making fine and friable the seed-bed.

In order to guide the farmer in respect to the application of the general principles here laid down, the following general suggestions are made.

When to Plow.

It has already been pointed out that plowing aids in the conservation of soil moisture. The question that naturally arises first, is what time shall plowing be performed in order to obtain the best results. It is obvious that for certain crops, as winter wheat or fall seeding of any sort plowing must be done in summer or early autumn, unless the land is fallowed, whereas for spring planted crops, as Indian corn, spring wheat, oats, barley and a number of others, it does not necessarily follow that plowing shall be done in the spring; fall plowing for these presents many advantages, though there are also disadvantages, and these must be carefully weighed before the practice is adopted. For example, the ideal condition of soil during winter is to have it occupied by a growing crop, because in this condition it readily absorbs and holds the moisture and prevents, in large measure, losses that occur through drainage from it of the soluble plant-food constituents, still the effect of freezing and thawing, and of oxidation, which take place when land

is plowed in the fall, oftentimes results in a greater increase in immediate fertility than is accomplished by allowing the soil to remain in sod during the winter.

Soils Suffer Loss of Water When Bare.

In the case of lands that are not plowed in the fall, but which are allowed to lie bare during the fall and winter, they become hard and compact, particularly clay soils, and the rainfall is not absorbed but is lost, because of the rapid surface drainage. Hence, on account of the loss in the drains and streams, the season's rainfall, which with care might furnish sufficient moisture for a maximum production, is deficient and the crops suffer.

Fall plowing, by opening up and making more porous the surface soil, permits the ready penetration of water into it, as well as its percolation into the lower layers or subsoil, where it is held for the summer crop. In fall plowing no attempt should be made to thoroughly fine the surface, or to make it smooth, for this will encourage the soil to run together, or compact, particularly those of a clayey nature. Of course, this fall plowing applies more particularly to soils of a heavy character, or those which are compact or stubborn, rather than soils of good physical character. Fall plowing on sandy soils would not be of any particular advantage, as they do not compact, and rains penetrate readily during any season when land is not frozen.

If fall plowing cannot be accomplished, then the plowing should be done in early spring, in order that the capillary connection between the disturbed surface soil and the lower layers may be established before the spring rains cease, this, followed by deep cultivation and thorough pulverization of the surface previous to planting contribute materially to the conservation of moisture.

Deep plowing also contributes to the absorptive power of soils, and conservation of moisture, because providing for a much larger area of soil for the penetration of the roots, and if practiced in the fall, the best time to increase the depth, the inert material thrown up weathers during the winter, and the resulting chemical changes also improve the physical character, as well as increasing the active fertility of the soil. If the plowing is left until the late spring, then deep plowing is not so advantageous for many crops, as shallow plowing, for if there is sufficient rainfall in the early season the surface soil is soon dried and the roots of the young plants have not had time to penetrate deeply enough to take advantage of the reservoir of moisture lying underneath, whereas, if the plowing is shallow the roots soon reach through into the solid bed below, which contains the moisture, and the plant is enabled to resist more effectually any drouth which may follow.

Cultivation After Planting.

In order to retain the moisture after the crop has been planted, cultivation should be deep, early, and gradually lessened as the season advances, in order that in the early season the rainfall may penetrate to the lower layers, and in the later season the mulch provided by the cultivation may not be so deep as to enable the complete drying of the surface soil. The advantages of continuous cultivation are also marked, inasmuch as every time the soil is stirred the connection between the lower layers and the surface is broken and the water below must seek new outlets for escape; and until these are obtained the water is retained for the use of the plant.

The method of cultivation also should be observed. On soils naturally well drained, cultivation in ridges contributes to the loss rather than the conservation of moisture, as the ridges lying so much above the main surface of the soil dries out more rapidly than if level cultivation is practiced. Naturally, in wet climates it is frequently advantageous to ridge the soil, in order to provide for the rapid drainage of the water, but in soils where the need is for water rather than for lack of water, ridge culture is not advantageous.

Frequent tillage, or continuous cultivation, also tends to increase fertility, by causing a more rapid change of the insoluble constituents into soluble forms. The constant stirring of the soil brings new particles into contact with sun and air. In soils rich in dormant or locked-up food, this method of improvement, which results in increasing their direct fertility is strongly commended, since it can be accomplished without any outlay of cash and by the regular labor of the farm.

Further Methods of Improvement.

Soils may be further improved, namely, in two directions, first, by saving in the soil for the use of the plants those constituents which by improvident and irrational methods of practice are likely to be lost; and second, by adding to the soil such amendments as may increase the activity of the constituents already there, or which may contain such substances as are essential for the growth of plants.

Losses Due to Methods of Practice.

One of the means whereby soils may become impoverished, or at least be reduced in productivity, is through the losses that occur from improvident methods. For example, it has been demonstrated that plants obtain their food in a soluble form, and unless it is taken up when it has become soluble there is danger of its being

carried away in the rains that pass through it. A saving, therefore, may be effected by keeping the land constantly occupied with growing crops, in order that food which is made available may be absorbed by the roots of plants and converted into organic forms which by their decay render it serviceable to other crops. The methods of practice quite common in the East require that the land lie bare at certain seasons of the year and some times for long periods, during which severe losses of plant food may occur, the chief element of which is the expensive constituent, nitrogen.

Experiments conducted by Sir John B. Lawes, at Rothamsted, England, showed that land in good condition, left bare from early fall until spring, would lose an equivalent of 37 pounds of nitrogen per acre. It was also shown that this could have been held and appropriated by crops. This loss of nitrogen may not seem a great matter at first glance, but a study of the losses in relation to crop production shows that it is really very serious. In the first place, this loss of nitrogen, which is possible and probable on good soils left bare, is more than equivalent to the amount contained in the average yield of wheat, rye, oats, corn or buckwheat; besides the nitrogen which is carried away by the drainage water, is in the very best form for feeding the plant, or it would not have been lost, and thus its absence leaves the soil not only poorer in this constituent element, but poorer in the sense that the remainder of it in the soil is in a less useful form. While the amount and time of rainfall cannot be controlled, its effect upon the soils in causing loss may be largely governed if proper attention is given to the matter of growing catch crops, in order that the land may be constantly occupied.

Another source of natural loss of nitrogen, is its escape as gas into the atmosphere, due to the oxidation of vegetable matter, which takes place very rapidly when soils rich in this substance are improperly managed. In the system of continuous cropping which is observed in certain sections of our country, the annual losses of nitrogen are much greater than the amounts carried off in crops, and while continuous cropping is not so generally practiced in the East the losses that occur, because of improper methods of rotation, which leave the land bare for any length of time, are very considerable. Indirect losses may occur, too, because the conditions are made unfavorable for the activities that are present in the soil. Take, for example, the rotation which allows the land to remain bare from the early part of July until September, when the rotation of corn, oats, wheat and grass is practiced. After the oat crop is removed in July the land is frequently allowed to lie uncovered, particularly in dry seasons, for a month or six weeks, during which

time the weather is often very dry, usually very hot; the temperature of the soil is raised to the point which reduces the activity, if not destroying altogether the soil organisms, and because of the absence of these the changes that take place later are very materially reduced. Rotations should be adopted which will permit the continuous covering of the soil by regular crops, or such catch crops as will keep the land covered between the seeding of the different ones in the rotation. A discussion of the crops adapted for this purpose will be found in subsequent pages.

There are also losses of mineral elements, which may be prevented by keeping the ground covered by the growing crops. For example, lands that lie bare during the late fall, winter and spring are liable to be washed and gulleyed, and the finer particles on the surface carried either away from the land or to such points as to make it impossible to utilize them in the growth of crops. This loss may be avoided if the above suggestions are followed.

Improvement Due to Soil Amendments.

Another method of improvement, which is partly chemical and partly physical in its character, is the addition of lime. This can hardly be regarded as a natural method of improvement, because additions have been made to the soil of substances not before present; still it differs from the addition of manures or fertilizers, which contain the essential fertility constituents, nitrogen, phosphoric acid and potash, as the improvement is due, not so much to the direct action of the substances added as to their effect upon the substances already in the soil. That is, the function of the lime is to increase the active fertility of the soil by action upon the substances there, and thus causing a greater absorption by the plant of the nitrogen, phosphoric acid and potash already in the soil, and without adding thereto that which was not there before. The three main ways that lime may improve soils are: First, *by attacking the vegetable matter*, thus assisting in the change of the combined nitrogen into active, and by the reaction of the lime with certain phosphate and potash compounds, rendering them available to plants. This function of lime, however, is only largely valuable on soils already rich in vegetable matter and mineral constituents.

The second function of lime *is to change the physical character of the soil;* for example, on heavy clay soil, whose particles are finely divided, and whose texture is so dense and compact as to prevent the easy penetration and movement of water, the lime helps to coagulate the fine particles of the soil, thus making it more open and porous, and permitting the penetration and free circulation of air and water. While upon the sandy soils, which are too loose and open and texture, and which permits a too free movement of water,

the effect of the lime is to cement the particles together and make the soil more compact, which increases its absorptive properties and a consequently greater retention in and utilization of the food in the soil by the plant.

The third function of lime, *is to neutralize any acid* that may be present in the soil, and which not only injuriously affects the growth of certain kinds of plants, but which is destructive to the life and growth of many of the lower organisms. Naturally this function of lime will be exerted whenever the lime is used for the other purposes mentioned, still there are cases where it would be desirable to use it only for this purpose, in which case the application may be much less. The advantage of lime in the growth of leguminous crops, for example, is not altogether because of the fact that this class of plants requires an abundance of lime, but because the lime exercises a favorable influence upon the physical character of a soil, besides making it neutral, and thus a better medium for the growth and development of the soil organisms, which have the power of gathering nitrogen from the air and which cannot thrive without air or in an acid medium.

The Importance of Vegetable Matter.

The lines of practice which have been suggested, in order both to prevent losses from soils and to improve their physical character, namely, the continuous cropping system, which holds fast to the available food in the soil, liable to be lost when the land is uncropped, and the addition of amendments which assist in making the necessary changes, also includes the further advantage of adding to the soil that which it did not before possess, viz: vegetable matter, or humus-forming material, which also improves the soil, not only in its absorptive properties for both moisture and plant food, but which contributes to the store of active essential constituents. The various crops that may be used to attain the first mentioned purpose, however, do not possess an equal value in this respect, and unless the principles which govern and the conditions under which they are grown, as well as the influence of the crops grown upon future productivity are well known the results obtained may not be always satisfactory.

Kind of Crops to Grow.

In the first place, the crops that may be used are divided into two distinct groups, in one group are included those plants which can obtain the necessary nitrogen for their growth only from soil sources and called "nitrogen consumers," and, therefore, when plowed down do not add to the soil any essential constituent element and are only

serviceable in improving the physical character and absorptive properties of soils. The members of this group include the cereal grains, the grasses, buckwheat, turnips, rape, etc., yet, because of their time of growth and period of rapid development, it is often desirable to grow crops of this class, particularly where the primary purpose is to prevent losses of plant food rather than to rapidly build up the soil in nitrogenous organic substances.

The second group of crops includes those plants which belong to the legume or clover family, and which do not depend solely upon soil sources for their nitrogen, but can obtain it from the air, these in their growth and removal from the soil need not materially reduce the content of soil nitrogen, but rather particularly when plowed down directly add to the crop-producing capacity of soils by improving their physical character and by increasing their store of nitrogen. In order that a plant of this group may obtain its nitrogen from the air, however, the soil must contain originally, or must be inoculated with a specific organism, the presence of which in the soil is manifested by the growth of nodules upon their roots and through which it is believed the plants obtain their nitrogen, though the exact process is not yet fully understood.

Advantage of Legumes.

The use of this class of plants, therefore, possesses a three-fold value in the improvement of soils, first, in absorbing and retaining the soluble food in the soil; second, in providing vegetable matter, or humus-forming material, which contributes to the physical improvement of soils; and third, by adding to the store of nitrogen in the soil, the element most likely to be deficient, and which can be used by plants whose sole source of nitrogen is the soil. Fortunately, because of the number of plants belonging to this group, and because of their wide range of adaptation to the various conditions, it is possible to introduce one or more of them into the regular system of farm practice, without interfering with useful and profitable rotations. Many of them, for example, the various clovers, red, crimson and alsike, are already grown extensively, and their value in the rotation well understood by practical men. There are many others, however, whose characteristics have not been carefully studied until recent years, and whose usefulness are just beginning to be appreciated. Among these are the Canada field pea, the soy bean, the cow pea and the various varieties of vetch, all possessing that valuable power of appropriating for their use the free nitrogen of the air, and thus contributing directly to the potential fertility of the soil. The plants of this group are often called, and properly, "nitrogen gathering" crops, and their renovat-

RYE.

ing and improving character are seldom over-estimated. A brief discussion of the various plants suitable as renovating crops, together with their characteristics and relative advantages must naturally precede specific directions as to their use.

Catch Crops, "Nitrogen Consumers."

The crop more generally used, primarily, to prevent losses during late fall and winter, is rye. The advantages of this crop for this purpose are that it may be seeded late in the year, after other crops have been harvested, grows rapidly, withstands the winter well, is a good forager, makes a rapid early growth, which may be plowed down for early crops as corn, potatoes, tomatoes, etc. Furthermore, the cost of seeding is small, and farmers are familiar with the handling of the crop. Its chief value, however, lies in its hardiness, withstanding well severe weather, and its habit of late fall and early spring growth, which holds the soil and prevents washing and mechanical losses; it readily absorbs the available food present in the soil, and even when plowed down early contributes in some degree to the humus-forming substances in the soil, and thus improves its absorptive properties.

Wheat possesses the characteristics which have been mentioned for rye, though not in the same degree. The seed usually costs more, and satisfactory growth requires a better preparation and fertilization of soil than for rye; besides, the plant is not so hardy and starts later in the spring. It is, therefore, as a rule, less satisfactory for the purpose than rye.

Buckwheat is another plant of this order, which has been used very largely as a soil improver, particularly in the breaking up of new lands, and for this purpose is a useful plant. Its season of growth is during the summer months of July and August, when conditions are usually favorable for the progress of those activities which cause changes in the soil substances, hence is able to make a relatively large growth on medium poor land; when grown as a renovating crop it improves the physical character of soils by keeping the soil covered during the hot season and by adding vegetable matter.

Certain varieties of the mustard plant are extensively used as a summer catch or fallow crop in other countries, particularly Germany; the plant grows rapidly and is able to subsist on rather poor soils, thus accumulating in the surface soil materials more readily appropriated by other plants. It, however, does not present any peculiar advantages for American conditions not possessed by the more familiar crops grown here.

The turnip also possesses characteristics of value, owing to its rapid appropriation of food in cool weather and consequent large growth during the late fall. These varieties which root deeply are preferable, because they gather a portion of their food from lower layers of soil and store it in their enlarged bulbous roots, near the surface; besides this peculiarity, the growth of the crop is an important factor, as it exerts a favorable influence upon the physical character of the soil. It causes a separation of the soil particles and permits a freer access of air. The disadvantages of the crop is that it dies at the beginning of winter. Still, if a considerable crop is grown, the mulch, consisting of roots and leaves, will hold the soil together, besides preventing as rapid a leaching as if the soil were entirely exposed.

Dwarf Essex rape is another plant that may be grown as a cover in the late fall and to serve as a mulch during the winter, and for these objects serves an admirable purpose, though possessing the disadvantages mentioned for the turnip.

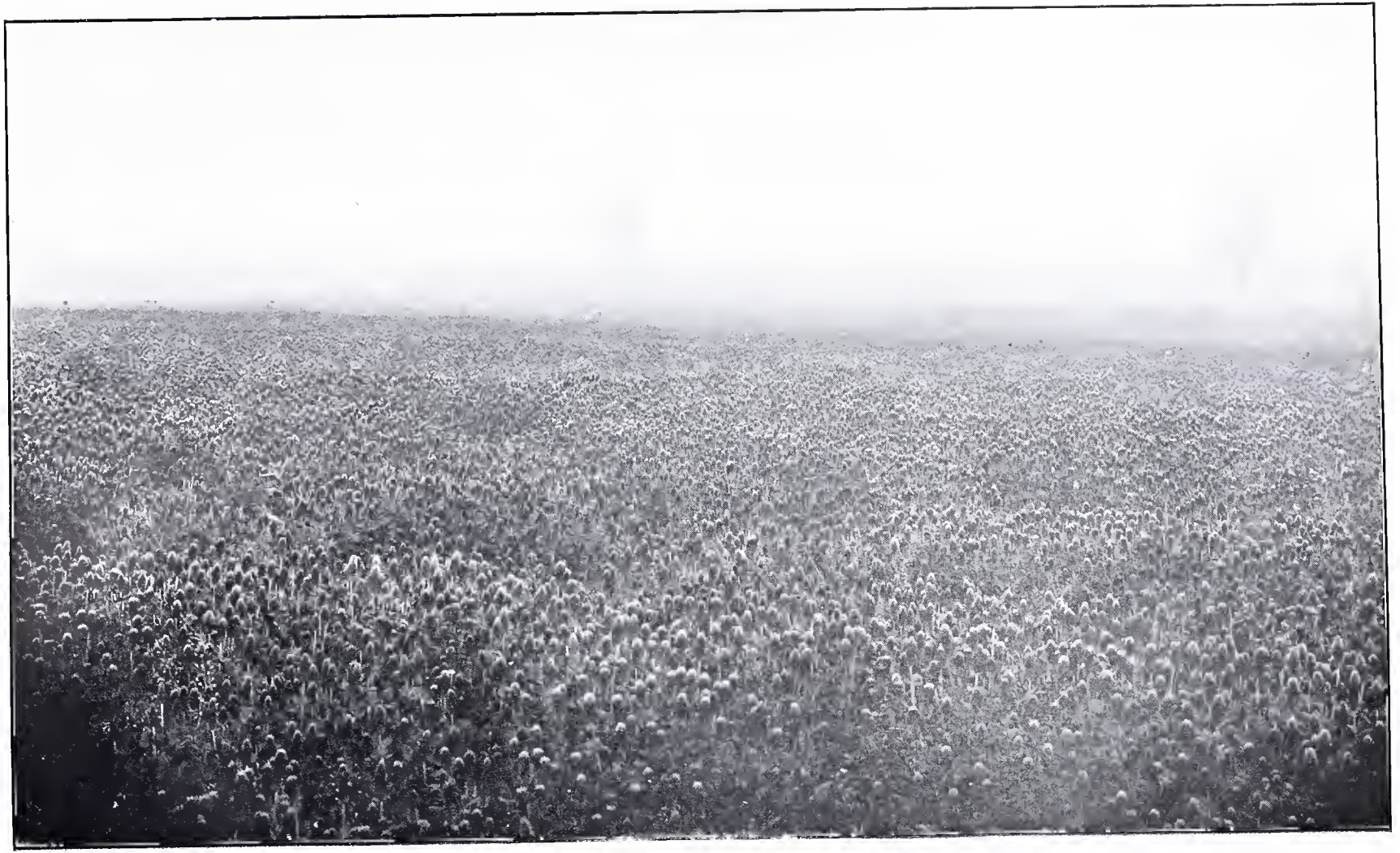
All of the crops here mentioned may be made virtually catch crops and thus not interfering with a regular rotation, and even if pastured or completely removed they leave the soil in a better condition than if no crop had been grown; the soil is improved, because its functions have been exercised and at a minimum expense.

Catch Crops, "Nitrogen Gatherers."

Of the "nitrogen gatherers," the clovers as a class are perhaps the best known, though it is believed that a brief description of the characteristics of the various useful plants belonging to this group will be helpful.

Red Clover.

The renovating character of a crop of red clover is well known, and even when only the stubble and roots are the source of the additions made to the soil, the improvement which follows is very marked. Farmers know that corn or wheat seeded on a clover sod will do much better than when seeded on raw ground or on sod from grasses. It is ordinarily a biennial though sometimes the life will continue through three seasons. Its characteristics are such as to make it adapted to a wide range of soils and of climatic conditions, though it thrives best on good soils, well supplied with humus. It is liable to be uprooted on wet soils by the alternate freezing and thawing in spring, and to be destroyed by hot weather on light sandy soils. The amount of seed to be used when the purpose is to secure the largest crop of clover is about 12 to 16 pounds per acre, depending on the character of the soil, the better the soil the less the amount of seed required.



CRIMSON CLOVER.

The ameliorating influence of this crop upon soils is due primarily to two causes, first, to the extensive root system, which is distributed widely throughout the soil, and to great depths in it, thus changing to some extent its physical character, as well as the storing up of food in a large tap-root near the surface of the soil, in organic forms, which readily decay; and second, because the plant is a "nitrogen gatherer," the crops of clover removed do not exhaust the soil of nitrogen, but rather add to its store, hence the succeeding crops have at their disposal a larger amount of this element than if they were preceded by the grasses or cereals, which are "nitrogen consumers." The wider and more frequent use of red clover can be commended from all standpoints, where the increase in and the maintenance of natural fertility are important, and in general farming these points are always important.

Mammoth clover is a near relative of the red variety and resembles it closely. It is a coarser plant and a greater forager; where clover is grown solely for use as a green manure the Mammoth may often be substituted with advantage for the red. It is also better adapted for wet lands than the red. The amount of seed used may be the same as for red clover.

Alsike Clover.

Alsike clover is believed to be a cross between the red and white clovers. It has a semi-creeping habit like the white variety and only does well when seeded with a variety making a more upright growth, as the red or Mammoth. The mixture is desirable, since the alsike is better adapted for cold, moist soils and is also hardier than the others, withstanding winters that kill the red and Mammoth varieties. A good practice in growing these varieties of clover with the cereals is to sow early in spring on the wheat or rye, seeded in the fall, and at which time timothy has been seeded, at the rate of 8 to 10 pounds per acre; the usual mixture of alsike and red is two pounds of the former to eight of the latter, using about eight pounds per acre. The seed of the alsike is so much smaller than the red that seeding in these proportions results in a very even mixture of the clovers. The seeding may, however, be made with advantage during the summer and early fall, without cover crop, either for turning under in spring as green manure or for hay or pasture. Such seeding should be made on soil well prepared and the seed lightly covered.

Crimson Clover.

Crimson clover is an annual, and because of its useful characteristics has made a place for itself in American agricultural practice.

Its habits of growth are not so well known as those of the other varieties described and for this reason, among others, is not so generally distributed even in those sections where it thrives well. Its habits are such as to make it undesirable to substitute it for the red, though it may well supplement it, and thus add another useful clover crop to our list. It is essentially a cool weather plant, thriving well in late fall and eary spring, and maturing seed in the middle States about June 1st. These characteristics of growth make it especially suitable for a catch crop, which may be used without interfering with regular rotations. It has proved hardy in the eastern and middle States, though many failures are reported, which are probably due in large part to the failure to observe in its seeding the peculiar habits and characteristics of the plant. The impression that because it is a catch crop it will grow well on poor soils with other crops, under all conditions of season and climate and without particular care in seeding, is erroneous. Like other plants, crimson clover must have food—it is affected by drouth and cold and severe weather; it cannot subsist with other crops, which rob it of moisture and plant food, and it must be carefully seeded, in order to insure against adverse conditions, though when conditions are favorable it will catch and grow from a simple sowing of the seed on raw ground. It should preferably be seeded at the rate of 12 to 15 pounds per acre, on a well prepared seed-bed and covered lightly with harrow or weeder. It is not suited for spring seeding, as it ceases to grow as soon as hot weather comes, the best period for seeding ranges in the eastern and middle States from July 15th to September 1st; it may, therefore, be used as a catch crop, seeded in corn, berry patches, orchards, etc., after the regular cultivation has ceased for the season and after early potatoes, tomatoes and other crops harvested early enough in the season to enable its roots to get a hold of the soil and to make considerable top before cold weather sets in. While it requires a good soil for its best development it is well adapted for light sandy soils if well supplied with mineral food. It will grow later in the fall than red clover, because not injured by frost, and also make a more rapid spring growth than any of the other clovers seeded in the late summer. Where the land is light and poor, a dressing of acid phosphate, say at the rate of 150 pounds per acre, will materially aid in securing a catch and insuring a crop. Its early maturity is one of its most valuable characteristics from the standpoint of its use as green manure, making it possible when seeded in corn, for example, to secure a considerable green manure crop, in time to plow down for another corn crop. When the plants are largely destroyed because of severe winters, the accumulated nitrogen and organic matter in the

fall is sufficient to amply repay the cost of seed and seeding. Studies made at the New Jersey Experiment Station show that a good thick crop, six inches high, will contain nitrogen and organic matter equivalent to that contained in five tons of yard manure; that the nitrogen is quite as useful for the corn plant as that contained in the manure, besides it is evenly distributed and there is no labor involved in its application. Another advantage of the crimson clover is that it is a spring green manure crop, thus permitting a return from it in the same season in which it is used. It will pay farmers to carefully study the habits of this plant and then to introduce it in their rotations as a soil renovator. If failures occur the cause should be learned and a remedy sought; discouragement should not follow one or two failures; remember that red clover sometimes fails. It has succeeded in many instances when red clover has failed.

Other Varieties of Clover Sometimes Used.

There are various other varieties of clover which possess useful characteristics, though with the possible exception of sweet clover, which is sometimes used in the south, they do not possess advantages superior to those varieties already mentioned. The sweet clover (*Melilotus Alba*), is a rank growing plant and is quite common as a weed along roadsides and in waste places. It is seldom cultivated, either for forage or green manure, though it seems to have the power of acquiring food from sources inaccessible to other plants of the same family. It thrives particularly well on soils rich in lime. Experiments with it in Alabama, Mississippi and Ohio show that it in common with other legumes aids in soil improvement. Its use is recommended only where other varieties do not meet the requirements.

Alfalfa.

Alfalfa belongs to the clover family and while one of the most valuable of this class of plants, from the forage standpoint, is not adapted for use as a green manure, because of the difficulty of securing a stand, and because of its comparatively slow early growth. It is a perennial, which does not reach its maximum annual growth until the second or third year after seeding.

The Field Pea.

The field pea, the variety that is used for forage, for cover crop or for green manuring, is usually known as the Canada field pea, though the name includes a number of varieties, as the Golden Vine, Prussian Blue, Green Field, Mummy, etc., any one of which is satisfac-

tory for the different purposes. This field pea does not differ in appearance nor characteristics from the ordinary garden pea. It thrives well in the more northern States, only in the cool moist weather of early spring and late fall, and for this reason is not adapted to sections south of the middle States, and its use as a cover crop, or for green manure is limited for this reason, as well as to the fact that it does not grow well except on good soils. Still, there are occasions when its use will meet conditions not provided for so well by other plants. For example, it may be seeded in September, or even early October, periods too late for the seeding of other legumes, and because of its rapid growth makes a crop before freezing weather; the crop serving as a mulch during the winter, preventing the wasting of sandy soils due to high winds, and the accumulated nitrogen and organic matter provide readily available plant food for spring sown crops. It has proved of great advantage in many lines of farming, where the crops are not removed early enough to permit the seeding of crimson clover, or other leguminous crop. It should be seeded at the earliest possible time in spring, and in fall, not earlier than September 1st, at the rate of one-half to two bushels per acre, and the seed well covered, preferably two to four inches.

Cow Peas.

The cow pea is probably neither a pea or a bean, as it differs widely from both, still it belongs to the same family, as do the clovers and field peas. Its origin is authoritatively stated to be the east, where it has been cultivated for thousands of years; it is believed to have been introduced into this country in the early part of the eighteenth century. Its best development is found in warm climates, hence in this country it has found a congenial home in the southern States, where it reaches its maximum development. A large number of varieties have, however, been developed which are adapted to cooler conditions, so that now it is well distributed even throughout the north, where it is proving itself one of the best annuals, and its adaptation to various uses and the rapid and large development of plant, make it one of the most useful of the legumes for soil improvement.

Varieties.

The natural tendency of the plant toward variation has resulted in a large number of varieties, though the permanent and distinct ones are comparatively few; the same variety is given a different name in different parts of the country, as, for example, one variety goes under the name of Unknown, Wonderful and Quadroon. In addition to the confusion arising from this practice. The selection of a variety is still further complicated by giving the same name to

COW PEAS.

a number of varieties, as, for example, the name of Crowder is applied to any variety in which the seeds are closely packed together or crowded. The further fact that the season and climate exert such an influence upon the plant as to make a variety in one place very different in its character than in another, makes it difficult to give positive advice as to the selection of varieties for specific purposes. The different varieties range in form from a bush a foot or so high, without runners, to those possessing vining or trailing habits, the vines reaching a length of from ten to twenty feet long, according to soil and season. The pods also range from four to eighteen inches in length, giving seed of every possible shape and form. The period of mature growth also varies, as do the habits of growth. The different varieties ranging in their time of maturity from two to six months, though the habit of growth does bear some relation as to the time required; the smaller the plant and the more nearly it approaches the bush form the shorter the time required for maturity, while the more rapid the growth and the larger and longer the vines the longer the time required. In order to select the proper variety for the various purposes, the object of its growth should be clearly understood. Where short, quick growth and maturity are required then, particularly in the north, the bush variety should be selected; whereas, if the purpose is for forage, and the period of growth can be extended, then the vining varieties are likely to be more useful.

In cases where they are grown primarily for green manures, then the time during which they grow should determine the variety to select. It is more difficult to select varieties for the north than for the south, as the plant has not been so carefully studied in this section. Nevertheless, the Early Black, Whippoorwill, Wonderful and Clay varieties have proved excellent for the various purposes. The Early Black, where the seed crop is desired, as it grows and matures quickly, whereas the others are better adapted for forage and green manure, as the longer they grow the larger the crop of succulent forage in one case, and of total crop in the other, except in the case of green manures, when only two or three months can be given to the growth of the crop.

Method and Time of Sowing.

The time of seeding the cow pea will depend upon the character of the weather; they should not be seeded in spring until danger of frost is past and the soil is thoroughly warm. In cold, backward springs many failures have been recorded, because of too early seeding; the seed are liable to rot in cold weather, and if germination takes place the plant is retarded in growth in cool weather and the crop is unsatisfactory even if

warm weather follows. This is of particular importance where they are seeded for forage or hay, as very often crops are failures because the seeding was so early as to cause the weather to injure the plant, and thus prevent its early growth. Neither should they be seeded later than two months before the average date of frost, as the first heavy frost will destroy the young plants and no variety that is now known will reach a satisfactory stage of growth for any purpose inside of this period. For forage and for green manure the crop may be sown broadcast at the rate of from one to one and one-half bushels per acre, or may be drilled in with an ordinary grain drill. If the seeding is not made too early, broadcast methods are very satisfactory. If, however, the early growth of the plant is retarded then weeds obtain a foothold and it is likely to be choked out.

Where the object of growing the crop is for seed, then planting should be preferably in drills, from two to three feet apart, or a little closer than for corn, and the amount of seed may be reduced to three pecks per acre. Seed should be covered from one to two inches deep and on very light soils a little deeper. The season to some extent governs the depth at which seed should be planted—in a dry season the deeper the seed the better. The difficulty in late summer seeding is that crab-grass is liable to choke out the plants.

There is perhaps no other crop that is so generally useful for soil improvement as the cow pea. In the first place it grows during the hot summer, when it is desirable to have the ground covered and its long tap-root penetrates into the subsoil, loosening it and making it more porous; and in the second place, the absorption and assimilation of the free nitrogen in the air by this crop, which is characteristic of all the legumes, makes it one of great service, even when the crop is used for forage and only the roots and stubble are left as additions to the soil.

In using the cow pea it may be plowed under while green, or may be left on the surface as a mulch during the winter, and plowed under in the spring. It may be partially grazed and the stubble and roots plowed under, and in any case the improvement of the soil is very marked. Where the forage can be used to advantage and the object is to gradually improve the soil, then the better plan is to remove it either for use as green forage or for hay, as on good soils the stubble and roots left will furnish sufficient nitrogen to supply the early needs of a cereal crop. On light soils it is also desirable to remove part of the growth, as the turning under of a too heavy crop of cow peas would be likely to injure rather than to improve the physical character of the soil. The danger from plowing under heavy crops of green manure is not so marked in the north as

SOY BEANS.

in the south, where the temperature range is high for a longer period. On heavy clay soils the improvement in plowing under heavy crops is very marked.

Soy Bean.

The soy bean has a strong central root, stiff stems, broad leaves and somewhat resembles the ordinary bean, though it is larger and bushier in form. The plants may be dwarf and early maturing, or late and tall, though in no case do they vine as do the vining and trailing varieties of cow peas. There are a number of varieties—the Green seems to be the variety most generally used and the crop from it varies according to the season and climate. This plant resembles the cow pea in many of its characteristics, namely, that it should not be seeded until the soil is warm, and where grown for forage it should be preferably planted in rows, in order that it may be cultivated. For green manuring purposes it may be seeded broadcast. The amount of seed per acre will vary from one to one and one-half bushels when broadcast, depending upon how well the seed are covered; when seeded in rows the amount of seed may be reduced to one-half bushel, or three pecks, per acre. The land should be put in good condition, in order that germination may be prompt. It does not possess, for green manure purposes, any characteristics different from those mentioned for cow peas. In fact, experience thus far shows that the soy bean is slightly more difficult to handle, and the yields are not so heavy, though the plant contains more nitrogen in the dry matter than the cow pea. It has been grown for green manure purposes when there has been a scarcity of the seed of the cow pea, and many prefer it to the cow pea, because it is easier to completely cover the plant in plowing, whereas a large crop of cow peas is particularly difficult to plow under. The decay of the plant will probably be quite as rapid as the cow pea, and hence serve quite as well as a source of nitrogen to the cereals.

Velvet Bean.

The velvet bean has attracted a great deal of attention lately in the southern States. It originated in the tropics, and has proved successful only in the southern States. In Florida it has been one of the most useful of the forage plants and is highly regarded as a green manure crop. It grows well on light, sandy soil and the yield is ordinarily about the same as for the cow pea. The season of growth is much longer, and for that reason the seed cannot be matured except in the south. The results of experiments conducted in the middle and eastern States show that it is not well adapted for these sections, and does not make as satisfactory a crop for any purpose as the cow pea.

Sand, or Winter Vetch.

This vetch is an annual, and is a native of western Asia. It has been recently grown wih success in the middle, eastern and southern States. It is a trailing plant, thus making it difficult to harvest for forage, unless seeded with some small grain, as wheat, oats or rye, to serve as a support. It may be planted either in spring or fall, at the rate of about one and one-half to two bushels per acre. It grows much better upon light, poor soils than cow peas or soy beans, and for such conditions is much superior as a green manure crop. The cost of seed thus far has practically prohibited its use, except in cases where small areas are grown.

Soil Inoculation.

The superior advantages of the leguminous crops as green manures, are due in large part to the fact, as already pointed out, that they are capable of obtaining their nitrogen in part, at least, from the air, a source inaccessible to the other class of plants. It must be remembered, however, that in order that this function may be exercised it is necessary that there shall be present in the soil certain organisms which attach themselves to the roots of the plants; their presence in the soil is indicated by the formation of tubercles or nodules on the roots, which range from a pin-head to a pea in size. Where these nodules are not present on the roots it is an indication that the proper organisms are not present and that the legumes, in common with other plants, must derive their nitrogen from the soil, and thus from the standpoint of accumulation of nitrogen they are, under these conditions, no more useful than the cereal crops.

Methods of Inoculation.

In view of these facts it becomes necessary in order to obtain the full benefit from the growth of the leguminous crops, to see to it that the proper organisms are present in the soil. This may be readily accomplished by inoculation, or introducing the specific organism into the soil. That is, soils in which these organisms are not present may be supplied with them by using a portion of the soil where they are present to introduce them. Experiments that have been conducted show that a small quantity only is necessary to accomplish the purpose, for example, a peck or one-half bushel of soil taken from different parts of a field which contains the organisms will, if sown broadcast over an acre which does not contain them, introduce the organisms, which multiply and distribute rapidly, and be prepared to do their work for the crop. Once

the organisms are present in the soil there is but little danger that they will be destroyed under good conditions of practice, and if the crops that are grown upon the area which has been inoculated are used as food for farm stock and the manure used elsewhere upon the farm the chances are that the organisms will be generally distributed, so that the work of inoculation is not a serious matter.

It very often happens that in the growing of such crops as cow peas and soy beans the first crop grown will not show the tubercles on the roots, but that the second one grown will be well supplied with them, indicating that the organisms are very often introduced into the soil by means of the seed, and seedsmen in some cases now make it a practice in harvesting their crops of soy beans and cow peas to pull them instead of cutting them, thus in threshing, mingling more or less of the soil which contains the proper organisms with the seed and which when removed leave the seed well inoculated.

The Amount of Nitrogen Gathered.

It does not follow, however, that even when these organisms are not present in the soil that all of the nitrogen contained in the crop of the legume grown has been gathered from the air, as it has been shown that the plants would preferably take soil nitrogen, and, therefore, that on good soils, well supplied with nitrogen, the proportionate amount of nitrogen drawn from the air will be much less than that will be the case when the crop is grown on soils poor in nitrogen. The exact amount of nitrogen gathered by a crop cannot, therefore, be exactly determined, though it is believed to depend upon the character of the soil, whether rich or poor in available nitrogen, hence the usefulness of the legumes as a means of acquiring nitrogen is greater when grown upon soils poor in this substance; these soils are, however, more greatly benefited by the accumulation than those previously rich in the element nitrogen.

The Importance of an Abundance of the Mineral Elements.

It has also been pretty clearly demonstrated that the proportion of nitrogen gathered by the plant from the air, particularly upon poor soils will depend upon the supply in the soil of the other necessary plant food ingredients. That is, soils poor in nitrogen and oftentimes poor in physical character if not well supplied with the minerals, phosphoric acid and potash, will not produce a large crop of cow peas or soy beans, or any other leguminous plant, because its grows and development depends upon the ease with which it may acquire the necessary amounts of the other elements of nutrition. Hence, in attempts to build up poor soils by means of green manure crops it is quite as necessary to fertilize with the minerals, in order

to insure maximum growth, as it would be in order to grow any other crop, the purpose of which is the crop itself, rather than for its effect in soil improvement. This is entirely reasonable, as the mineral constituents cannot be attained from any other source than the soil, and they are quite as essential in the complete growth and development of a crop as is the nitrogen.

The point is, that green manuring does not result in building up and making better a soil that is naturally poor in the mineral constituents. It can only contribute the nitrogen, and that in itself is not a complete food, it is only one of the essential, though very important elements. On heavier soils, overlying strong subsoils, as, for example, clay loams, and which are usually rich in dormant mineral constituents, the practice of growing the legumes may result in building up the soil, both in available nitrogen and in available minerals, as these plants have the power of acquiring the minerals from such soils more readily than certain other classes of plants, and thus by their growth there is an accumulation of nitrogen, as well as an accumulation of the mineral elements in a more available state, and the soil is improved in all directions without the direct addition of any fertilizing substance. The roots running deeply in the soil and subsoil gather the mineral food and store it in their larger roots near the surface, where it is not only available from the standpoint of other plants reaching it, but available from the standpoint of its being more readily acquired by them. Such soils may be improved and kept in a high state of fertility by the frequent growth of a renovating crop, whereas, on light soils which are poor in all constituents, the improvement will be in proportion to the amount of minerals supplied, as they will measure in a degree, at least, the rate of appropriation of the nitrogen. These considerations are practically true for all of the plants in the group of legumes that has been considered, though the different plants may apparently differ materially in their rapidity or degree of growth, even on the same soil and without the addition of other materials. The fact remains, however, that genuine improvement of poor soils cannot be expected from the growth and use of green manure crops alone.

The Plowing in of Green Manures.

Another point that should be clearly understood in the matter of soil improvement by means of green manures is the time for plowing down the crop. In the first place, the character of soil exerts an influence on this point. As a broad, general rule, there is danger of injury to light soils in plowing down a heavy burden of green material, particularly in warm weather, whereas upon heavy soils

the danger is very much less, and in fact ordinarily quite remote. Hence, in the discussion of the subject the influence of the season of growth of the plants is worthy of consideration. If the crop which is intended for green manure matures rather early in spring, then the time of plowing under must be governed by the purpose of the growth of the crop which follows, as its development will be materially influenced by the operation. Take, for example, rye, representing the class of "nitrogen consumers." This crop makes a rapid, early development, and if allowed to entirely mature it not only draws heavily upon the available food constituents of the surface soil, but rapidly and often completely exhausts it of moisture. Hence, if plowed down in its mature state it will result in leaving a mass of vegetable matter not readily decayed between the surface and the subsoil, thus cutting off absolutely the connection between the surface and the reservoir of water lying below. Should, therefore, dry weather follow, the decay will be very slow and the succeeding crop will have only the food and the moisture that are contained in the surface soil turned over, and from this the available food and the moisture have been largely extracted by the maturing of the large crop of rye.

Spring Green Manure Crops.

Hence, it is readily seen that the time of plowing down the green crop is a matter of the very greatest importance. Rye is an excellent green manure, if properly used. It should, therefore, be plowed down not later than when just coming into head, when the vegetable matter is immature, which readily breaks down and decays, and when the smaller growth of the plant has made but little demand upon the soil for moisture. Furthermore, in this early stage of growth the vegetable matter does not make so bulky a mass between the surface and subsoil, and thus the capillary connections between the upper and lower layers are readily made, and hence not preventing the next crop from securing its needed moisture.

The principles involved here are practically the same for crops of a leguminous character. For example, crimson clover, which has been seeded in corn, or that has been seeded in orchards for the purpose of accumulating nitrogen, also prevents mechanical losses and contributes to the improvement of the physical character of the soil. Still, the time of plowing down the crop is of the very greatest importance, not only in its influence upon the character of the soil itself, but upon the growth of the subsequent crop. Should the crop mature, and the weather conditions be entirely favorable, and there is sufficient moisture and warmth, then no danger may be

apprehended in allowing it to mature, but if the primary purpose is not to secure the full benefit of the clover crop, but rather to ensure the growth of the succeeding crop, whether it be corn or peaches, pears, plums, etc., then the use of the crop, its time of plowing down, should be made when it will not interfere with the primary purpose in its growth.

Fall Green Manure Crops.

In the case of crops that are grown during the summer the considerations in reference to soil still hold true, and even in a greater degree, since crops plowed down during the summer are more liable to rapid fermentation than those plowed down in the spring. Trouble from soil acidity may result from plowing down in the late summer or fall crops grown in the summer, still, the results of such practice will depend considerably upon the time that they are turned down and the character of the weather which follows. Cow peas, for example, that have been seeded in July and have grown through August and September may be plowed down in October without any danger to the succeeding crop or soil, unless the weather conditions are very unfavorable, as, for example, dry and hot, in which case the dangers pointed out in the turning down of the rye in the spring in its mature state would be likely to follow. Otherwise, if the weather should continue moist and hot, the rapid decay of the vegetable matter would be likely to result in a too rapid fermentation, probably inducing acidity of soil; this would not be likely to be a real danger except upon very light, open soils. On heavy clay soils, where the texture is more dense the tendency would be to prevent the too rapid entrance of air, and thus cause a more uniform decay.

When to Lime.

Where the crop is very large and where the conditions pointed out here are anticipated, the better practice will be to remove in part at least the burden of crop. It is desirable, also whether in the spring or fall use of the manure crops, to see to it that there is sufficient lime in the soil to assist in the fermentation, as well as to neutralize acids that may be developed. Hence, where green manuring is practiced, there is greater need of the occasional application of lime. It is not necessary that it shall be applied in all cases, since the application of, say 25 bushels of stone-lime per acre, in a rotation once in four years, would be likely to meet all the needed requirements for lime. If these suggestions are observed in reference both to soil inoculation and the plowing in of the green crops, there is no question as to the advantages that may

be derived from the practice. It will result, not only in building up soils poor in that important element, nitrogen, but will contribute materially to the improvement of their physical character, the water-holding capacity, and their consequent crop-producing power. On soils rich in potential fertility, the continued and judicious use of green manures will materially improve the mechanical character of the soil, not only, but will be very influential in the maintenance of fertility, without large additions of the minerals, phosphoric acid and potash.

The Amount of Nitrogen Contained in Average Crops.

While it has already been pointed out that it is very difficult to estimate the amount of nitrogen that the leguminous crops will draw from the air, the following tabulation shows the nitrogen and organic matter that are contained in an ordinary crop of the various plants:

	Tons Per Acre Green.	Nitrogen. Lbs.	Organic Matter. Lbs.
Cow peas, ...	6	48	1,920
Soy beans, ...	6	60	2,640
Crimson clover, ...	6	60	2,160
Alsike clover, ...	6	60	2,640
Red clover, ...	6	60	2,400
Canada field peas, ...	5	50	2,200

If the amounts of nitrogen indicated in the table as contained in a crop that can be harvested were all gathered from the air, there would be an undoubted increase in the fertility of the soil, as the amount of nitrogen gathered is equivalent to that contained in from 320 to 400 pounds of nitrate of soda, which amount would be regarded as a heavy dressing for even vegetable crops. Interpreted in terms of yard manure, the nitrogen and vegetable matter would be equivalent to from six to eight tons of average yard manure. It must be remembered too, that the yields given are not large, and that they do not include the amount of nitrogen and organic matter that may be contained in the roots and stubble, which in the case of the clovers is very considerable.

Furthermore, experiments have shown that the rapidity with which the organic matter will decay and give up its nitrogen to the cereal group of plants, is such as to make this source of nitrogen compare favorably with that contained in the average commercial fertilizer. The fact that so large an amount of nitrogen is introduced by means of green manures, whether entirely drawn from the

air or not, makes it important to use care, in order to prevent too large accumulations of this element. The danger, particularly in the case of certain cereal crops and fruits, is that the excess of nitrogen would be likely to cause an abnormal growth, that is, an undue leaf and wood growth. As in all other lines of farm practice, it is the judicious use of nitrogen that results in maximum returns.

Practical Application of Principles.

In order to give the most practical information to the farmer, the discussion of the use of the various plants described will be considered, first, in reference to those grown for the primary object of preventing losses in soils, and their consequent indirect improvement, due both to the saving of valuable soil constituents, and to the addition of vegetable matter; and second, in which the object of use is primarily to build up wornout or run-down soils, both in their physical character and their nitrogen content. In order that the matter presented may be directly applicable in present practice, it is necessary to select a method of practice now largely followed and which if continued will result in loss, and point out how the plants may be used and losses may be prevented, and what the gains are likely to be other than the saving of the food in the soil.

The Losses that May Occur in Rotation.

The common rotation of corn, oats, wheat or rye, and clover, may be taken as an example, because as usually conducted it is wasteful of fertility, due to the fact that no improving crops are introduced between the cereals, and only one in the rotation, and if the clover fails there is no renovating crop grown. By this practice it is impossible to prevent losses due to leaching, since the land is left bare for a part of two years. The sod land is used for corn, if it happens to be clover, the striking benefit of the clover in furnishing an abundance of nitrogen is apparent. The corn crop is usually harvested in early September, at a time in the season when, because of favorable conditions of weather preceding, namely, warm and moist, there has been an accumulation in the soil of nitrates due to the breaking down of the vegetable matter contained in the clover crop. After the removal of the corn, the land is left bare, except possibly a few annual weeds, the nitrates that have been formed and are ready to immediately feed another crop, and which are freely movable are carried away into the drains by the heavy rains liable to come in the fall. If heavy rains do not come in the fall, then the spring rains, which come before another crop is planted, carry at least a part of the nitrates so essential for the

nourishment of the early seeded crop away from the soil. The further disadvantage is that with the soil bare during this period of five or six months, the mechanical losses due to the high winds of winter and spring and to the washing of the surface are very considerable, especially on light land.

The losses that have resulted because of these conditions leave the soil depleted of a part of its active constituents, hence when the oats are seeded in the spring the crop may start promptly, due to the nourishment contained in the seed, but this consumed, the young plants soon become hungry for food, the available nitrogen, which is necessary for a rapid growth is lacking and it does not make proper development until the conditions of warmth and moisture are again favorable for causing changes to take place in the soil, unless directly fertilized or manured. After the oat crop is removed, usually about the middle of July, the land lies bare again until the seeding of wheat or rye in September. During the summer season, the losses from leaching are not likely to be so serious, except in seasons of unusual rainfall, but if not wet, the weather is usually very hot; the rays of the sun strike direct into the soil and the temperature, particularly if it is sandy, rises very high—the soil becomes dry and hot, in which case the organic life present in the soil is likely to be destroyed. That is, because of the high temperature at this season the soils are not improved by lying bare, but rather injured, and when the fall crop is sown, instead of an accumulation of available food in the soil, for the wheat or rye, there is a deficiency, because the agencies active in promoting changes of dormant into active foods have been in part destroyed. The succeeding year crops must, therefore, be fertilized to ensure a good start, and a sufficient root-hold upon the soil to carry them through the winter. These, in brief, are the unfavorable conditions in a rotation of this sort, a rotation in many ways a desirable one, but which as ordinarily conducted results in a rapid exhaustion of soil, though one which permits of great improvement if properly modified by the use of catch crops.

The Use of Catch Crops Improves the Rotation.

In order to prevent losses, as well as to provide for an accumulation of food in the soil, the following suggestions are made: In the first place, crimson clover may be seeded in the corn, just before the last shallow cultivation, at the rate of 12 pounds per acre. If the seed is well covered it will germinate very quickly, though the plants may not make much growth until after the corn is removed, owing to the rapid absorption of food and moisture by the corn in the last stages of maturity. The plants will, however, then start

up and grow rapidly and if the weather is favorable often cover the ground with a mat six or eight inches thick, filling the entire surface soil with fine rootlets, which absorb and hold fast to the available nitrogen already there, and which would otherwise be lost, besides, they would acquire from the air a part at least of the nitrogen which is so valuable an element. This crop would, too, hold fast to the soil and prevent mechanical losses due to washing, so liable to occur in winter.

In many cases it is desirable to pasture because the large fall growth of the clover, if not removed, will increase the danger of smothering in winter. Should, however, the conditions not be favorable and the plants die before spring, the nitrogen in the fall crop, either absorbed from the soil or accumulated from the air, will amount to an equivalent of five to six tons of yard manure per acre, in addition to the improvement of soil due to the considerable organic matter in the crop. The crop may be turned under at any time when it is convenient for the oats which follow the corn, thus not interfering in any way with the rotation, though naturally the amount of food gathered for the oat crop will be small, owing to its early seeding. The gain here is chiefly due to the prevention of losses. When there is injury to the clover crop, due to very dry weather following seeding, or because of unfavorable conditions which make careful seeding impossible, the advantages gained by the use of this crop may be in part attained if with the clover is mixed seed of the turnip, or Dwarf Essex rape, a half pint of seed per acre of each of these plants, used with the clover seed, using the same amount of clover, will be sufficient to give a considerable number of plants per acre, and will not interfere with the growth of the clover, should the conditions be favorable for its development, and if not, then the covering of the soil by the plants of the turnip and rape will be sufficient to absorb and retain food that is liable to be wasted, besides there will be an accumulation of vegetable matter useful in the improvement of the soil and in the feeding of other crops. The soil will be covered, even though the plants die, with a mulch of vegetable matter that will prevent the washing and mechanical losses due to heavy storms. Where neither crimson clover, turnips or rape are regarded as available plants for the purpose, then rye or wheat may be seeded at the last cultivation of the corn, at the rate of one and one-half bushels per acre.

By this method of practice a growing plant of the "nitrogen consuming" class is used, which will in its growth hold fast to the available food liable to be lost, besides filling the ground with roots and preventing mechanical losses. This crop may be turned under

early in the spring without interfering with the rotation, though naturally the only gain will be the saving in the soil of food that would be liable to be lost. The chief advantage of the nitrogen consuming crops when used for this purpose, has been, as will be observed from the previous discussion, is to hold fast to food that may be lost, as the growth of the crops will not in any large degree increase the constituents in or improve the properties of the soil, as the oats seeded early in the spring will prevent the crops from making any considerable accumulation of food from soil and air.

The next point to be considered is the protection of the soil, as well as its possible improvement after the oats are harvested, and before the succeeding crop is planted. It is preferable in this case, of course, to use a plant which will accumulate nitrogen from the air, renovating rather than exhaustive in its character, as the crop which follows, namely, wheat or rye, is a nitrogen consumer, whose entire and only source of nitrogenous food is the soil. A nitrogen consuming crop, as millet, for example, or even buckwheat, would use too completely the available food in the surface soil, converting it into organic forms and hence make the conditions of soil less favorable for the wheat in respect to available plant food, than if the crop had not been grown. Furthermore, a crop must be grown which develops rapidly, in order that a large accumulation of nitrogen and organic matter may be made in a short time, say six weeks or two months. For this purpose, therefore, no better plants can be suggested than the cow pea or soy bean.

It is not necessary in the seeding of these plants that the land should be plowed after the oats are removed, if the surface two or three inches of soil can be made fine with a Cutaway harrow, in fact, this is a better practice than to plow, as the losses of moisture due to the preparation will be much less and the possible effect of dry weather in part avoided. Hence, immediately after the oats are removed prepare the land and seed cow peas or soy beans at the rate of one and one-half bushels per acre; they may be broadcasted, harrowed in, or put in with the grain drill, and preferably dressed with 250 pounds per acre of a mixture of four parts of acid phosphate and one part of muriate of potash. This added fertility is to ensure an abundance of available mineral food, so necessary in order that the plant may be induced to appropriate nitrogen from the air. This, of course, will remain in the soil for the use of the wheat or rye, which follows. At this season, if there is sufficient moisture, the plants germinate quickly and grow rapidly and will in six weeks make a considerable crop.

The advantages of growing a crop of this character are, first, that the soil is very soon covered with a plant of a large leafy growth,

thus protecting the soil from the direct rays of the sun, and preventing the destruction of organic life, due to hot and dry conditions, and in the second place, there is an accumulation of nitrogenous vegetable matter, which when plowed into the soil is useful for the succeeding "nitrogen consuming" crop; and third, there is no interference with the growth of the regular crops of the rotation. That is, even though the period of growth is not long enough to cause the complete development or full maturity of the plant, it can be turned under when convenient, with the satisfaction of knowing that even though a small crop has been secured the soil is better, both physically and chemically, for the growth of the following wheat crop than it would have been if the land had been left bare.

Failures Should not Discourage.

As in the case with a number of other crops, failures sometimes occur, particularly in the catch of crimson clover. This is not always due to the season, though frequently such is the case. It is my judgment that the failures are more frequently due to the lack of proper preparation of the soil and seeding. In many cases the plants are starved in the beginning because the rapid growing of the corn absorbs the food and moisture, hence, if the seeds are placed deeply the danger from this source is not so great. It often happens too, that the preparation of the land for corn and its cultivation have not been of the best; the land is hard and cloddy and thus too little food is available for the clover. Sometimes, too, the soil may be slightly acid, which would make it an unfavorable medium for the growth of the soil organisms, whose presence have so important a bearing upon the growth of the crop; strict attention to those points which are important in the growing of any money crop is quite necessary in the successful growing of catch crops. It is recommended that where failures have occurred that the seed be covered more deeply and that in the preparation for corn the land be well tilled and preferably limed, say at the rate of 25 bushels per acre, either the year before planting on the sod, or early in the spring after plowing, and well harrowed in, and on land not in a good state of cultivation, this practice should be followed by a broadcast dressing of acid phosphate at the rate of 250 pounds per acre. The lime will neutralize the acidity of the soil, the acid phosphate will ensure an abundance of available phosphoric acid for the plant, which requires considerable in its early growth and a deeper seeding will cause a better hold of root and enable the plant to withstand a lack of moisture, which is one chief difficulty encountered in the seeding with corn. In the growing of the cow pea, after oats, it is very desirable if the best results are to be obtained,

that the plant have at its disposal a sufficient amount of available phosphoric acid; the addition of this for the benefit of the catch crop will not be lost, but be recovered again by the crop of wheat, and by making conditions favorable for the growth of the cow pea the plant is in a position to fully exert its function in the way of appropriating nitrogen.

Danger of Injury to Soil by Green Manuring.

A word of caution should be given concerning the turning under of green crops as manure. If the conditions of season are not favorable, i. e., too warm and moist, the land may be injured rather than benefited by the turning under of so large a mass of material. It may ferment or change too rapidly, the rapid decay developing an acid, which may be so great as to cause injury to the soil. If, on the other hand, it is too dry, the crop does not decay for some time; a mass of vegetable matter lies between the surface and subsoil, which prevents capillary attraction, and results in a greater drying of the surface soil than would be the case if no crop had been grown. In either of these cases the possible disadvantages should be recognized. Hence, where a crop of some size is turned under in hot weather it is desirable to add lime, which will neutralize the acid and assist in the decomposition of the vegetable matter. If the crop is too heavy, a part at least should be removed and great care taken to thoroughly "firm" the soil after it has been turned down. It is also well to remember that a too frequent turning under of heavy green manure crops will rapidly increase the soil's content of nitrogen, and unless large applications of minerals are made, the soil may become so rich in this element as to cause too great a leaf growth of the cereal plants. When this stage is reached the practice should be changed, the crop of cow peas should be used as before, but preferably used as forage or made into hay, and only the roots and stubble turned under for the wheat. The chances are that in most cases this would be the better practice from the standpoint of soil improvement—it certainly would be a more economical method of practice where the forage can be used to advantage.

The Application of the Principles in Other Rotations.

The principles that have been pointed out in this discussion relative to the addition of crops that may be used in this rotation, in order to improve the soil, hold true for other crop rotations, when the land is left bare for any considerable period, and also in reference to the improvement that may come from the introduction into the soil of considerable vegetable matter containing nitrogen, which

has not been drawn from soil sources. Still, suggestions as to changes in practice which may result in increasing the area and yield of more useful crops may be of service. For example, in growing corn, it has been demonstrated beyond a doubt that this crop may be grown on good land many years in succession on the same land, while at the same time maintaining, if not increasing, the yield of crop, provided a crop of crimson clover is grown and plowed down. That is, because of the holding fast of the soluble constituents liable to be lost in fall and spring, and because of the accumulation of vegetable matter and of nitrogen, by virtue of the clover crop, the corn is supplied with a greater abundance of mineral elements and of nitrogen each year, and the soil is not exhausted of its vegetable matter.

Soils naturally rich in minerals, with the improved physical character, due to the introduction of the catch crops, will provide the corn plant with a full supply from year to year without direct or heavy applications of fertilizer supplies. This practice would be very desirable on dairy farms, where a large yield of corn for the silo is an important factor. It may be modified still further and made more profitable by using a part of the clover instead of turning it under, as in the middle States the clover will be ready to harvest from the middle of May until the first of June, depending upon the season, or in time to permit the proper maturity of corn planted after that date. Hence, when the clover is seeded for the purpose of using in part on pasture, forage or hay, the land should be cultivated as nearly level as possible, and the corn stubble broken down or rolled off in winter. The crop may be pastured earlier than any other clover, and it may be cut for green forage or hay by the 20th of May, or in time for the planting of another crop. The removal of the clover, of course, results in reducing the amount of vegetable nitrogenous matter introduced into the soil, and for best results the soils should be matured in addition to the application of the mineral constituents, though in many cases the harvesting will be imperfect and a very sufficient amount left to considerably increase the supplies for the corn crop.

Where the rotation consists of corn, late potatoes, wheat and clover, the crimson clover seeded in the corn may be allowed to partially mature, thus making a very considerable addition of food to the soil for the potato plant. This is a very excellent rotation, resulting in very materially improving the soil, particularly when the potato crop is a profitable one, as it enables the use of two clover crops, both contributing to soil improvement, besides, the potato is not an exhaustive crop. In this rotation the cow pea could not be readily introduced, as the wheat should be sown almost immediately after the potatoes are removed.

Modifications of various rotations may be adopted and the usefulness of the proper catch crop very easily demonstrated. The main points to be observed is to keep the soil covered between crops with a leguminous crop, if possible, but with some crop, in order to be sure of this; in the case of the corn a mixture of the crimson clover and other seeds, as turnips or rape, may be made, so that the catch is there in any case, though if only the fall growth is obtained, the advantages of a fall covering are many, namely, a very handsome return is obtained on the investment for seed and the labor involved.

Improvement of Poor or Rundown Soils.

Where soils are poor, and the primary object is to build up or make "condition" rapidly, rather than to secure money crops, the leguminous crops should be more generally and continuously used. The land, for example, which has been run down, lacks both chemical and physical character. The crops grown have been exhaustive, the land badly cultivated and condition such as to make it unprofitable to use direct fertilization for the purpose. The questions are what crops shall I use and how shall I use them to the best advantage in order that money crops may be grown the second year?

If it is necessary to begin in the spring, the first crop used may be the Canada field pea. This should be seeded deeply, as early as it is possible to prepare the land, at the rate of about two bushels per acre, and the land should preferably receive a dressing of say 500 pounds of a mixture of 400 pounds of acid phosphate and 100 pounds of muriate of potash per acre. This crop may be plowed down, in our middle States by the first of July, and may be followed immediately by a crop of cow peas, seeded as already recommended and without further fertilization, and this crop plowed down by the middle of September, the land preferably limed at the rate of 25 bushels per acre, obeying in both cases the precaution to thoroughly "firm" the soil by rolling. This may be followed by a seeding of rye and sand vetch, one bushel of rye and one bushel of vetch, preferably fertilized with a dressing of 200 pounds of acid phosphate and 200 pounds of ground tankage per acre, preferably to secure a good catch and growth of rye. This combined crop may be turned under in spring for corn, without the further addition of fertility elements, and a rotation, the adoption of which is suitable to soil and conditions, provided it permits of the introduction of leguminous catch crops.

Here we have in one season, or previous to the planting of the

corn, three crops of a leguminous character, which should very materially change and improve the character of the soil, making a heavy soil more open and porous and absorptive, and a light soil more compact and retentive, besides furnishing a very considerable percentage of nitrogen available for the succeeding crops. Naturally, if the soil is poor it will be necessary to continue with as many leguminous crops in the rotation as it is possible to introduce. For a year or two at least, keeping the number of money crops in the rotation as low as possible.

The object of this work is to point out, so far as it is known to the writer, the principles involved in the natural improvement of soils; with these understood the individual farmer will be better capable of selecting his crops useful for the purpose than any one else, as he is familiar with his climatic and seasonal conditions, his own soil and its adaptation for the various crops, both "catch" and "money." He should remember, too, that the knowledge of these things is yet very incomplete and that he must not rest satisfied with the improvement that may be obtained by its use, but to take advantage of such further additions as may be made from time to time, as the resut of scientific investigations.